

ELECTRONIC FUNDAMENTALS

EXPERIMENT LESSON 14

INDUCTANCE EXPERIMENTS



RCA INSTITUTES, INC.

A SERVICE OF RADIO CORPORATION OF AMERICA

HOME STUDY SCHOOL

350 West 4th Street, New York 14, N. Y.

Experiment Lesson 14

OBJECT

1. To study the effect of inductance in d-c circuits.
2. To study the effect of inductance in a-c circuits.
3. To study one method of measuring inductive reactance and inductance.
4. To study the effect of mutual inductance in a-c circuits.

PREPARATION

1. To prepare for these experiments, read and study Theory Lesson 14. When you are sure that you understand the theory of inductance, do these experiments. Try to account for everything that you observe while doing the experiments. If you come across something that puzzles you, do not hesitate to go back to the theory lessons for an answer.

2. Study the sections of Service Practices 14 dealing with the identification of power-transformer windings.

INFORMATION

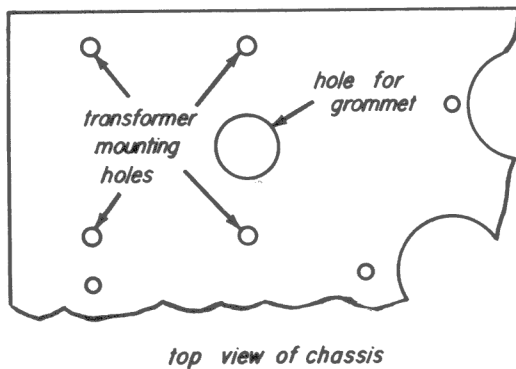
Many of the experiments in this lesson, and in lessons to follow, will be performed with parts that you will mount on the receiver chassis that you received in Kit 7. To prepare the chassis for the experiments to be done in this lesson, it will be necessary for you to mount some parts and wire them so that they may be conveniently used. While the wiring connections are to be soldered, most of them will be temporary connections. For these connections, use the method for soldering temporary connections that you learned in Experiment Lessons 1 and 2. Wherever a permanent connection is to be

made, the instructions will call for such a connection in the step where the work is to be done.

Be careful with the parts as you mount and use them because later they will become part of the radio receiver that you will assemble in this course. Be sure to mount each part exactly according to the instructions. The holes punched in the chassis are placed so that each part may be mounted without straining or forcing. If a part does not seem to fit a hole, recheck the position of the hole with that in the illustration so that you can be sure that it is the correct hole.

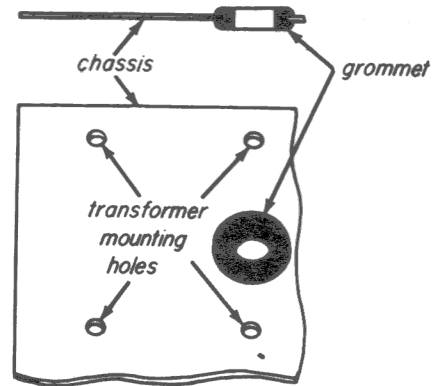
EQUIPMENT NEEDED

- Four 1.5-volt flashlight cells
- Filter choke
- Multimeter
- A-C line cord and plug
- Power transformer
- Neon lamp NE-51 (from Kit 2)
- Pilot-lamp socket (from Kit 3)
- Receiver chassis
- Hardware
- Hook-up wire
- Soldering iron and solder
- Two alligator clips (from Kit 1)
- Shielded lead with clips (from Experiment Lesson 2)
- 390-ohm 1-watt resistor
- 10,000-ohm 5-watt resistor

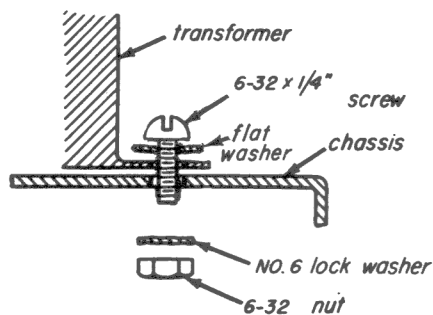


top view of chassis

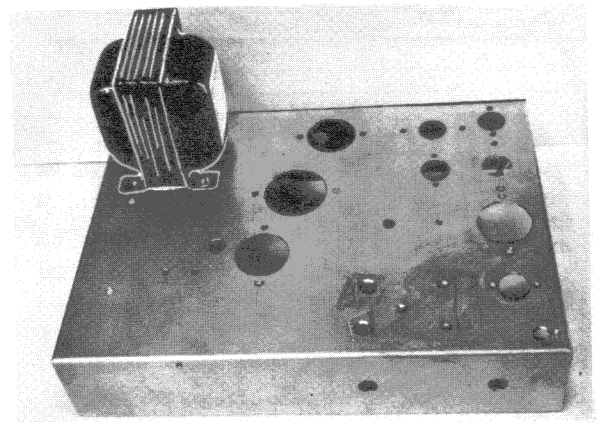
(a)



(b)



(c)



(d)

Fig. 14-1

JOB 14-1

To mount the power transformer on the chassis.

Procedure.

Step 1. Place the receiver chassis on your bench and locate the four power-transformer screw holes by comparing the chassis with Fig. 14-1a. At the same time, locate the hole for the transformer leads.

Step 2. Place a 1/2-inch grommet from the hardware kit in the transformer-lead hole, as shown in Fig. 14-1b.

Note: In wiring a radio or television chassis, any wire passing through a hole in the chassis should be insulated from the sides of the hole by means of a grommet. This prevents the possible wearing away of the insulation (if any) of the leads and prevents conductors from shorting to the chassis

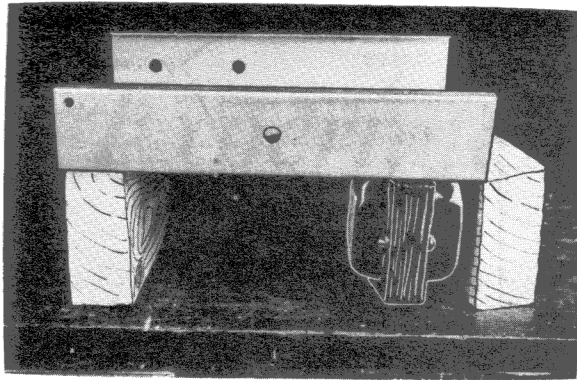
when their insulation ages and breaks down. Whenever you run a lead from the underside to the topside of a chassis, be sure to use a grommet.

Step 3. Thread the power transformer leads through the grommet and line up the four mounting holes on the transformer with the holes that are punched in the chassis.

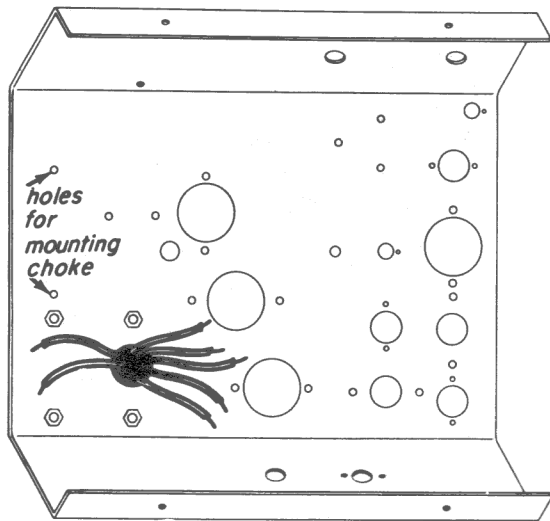
Step 4. Fasten the transformer to the chassis with four 6-32 x 1/4 inch screws, four #6 flat washers, four #6 lock washers, and four 6-32 nuts, as shown in Fig. 14-1c. The transformer is now mounted permanently and should appear like that shown in Fig. 14-1d.

JOB 14-2

To mount the filter choke on the underside of the chassis.



(a)



(b)

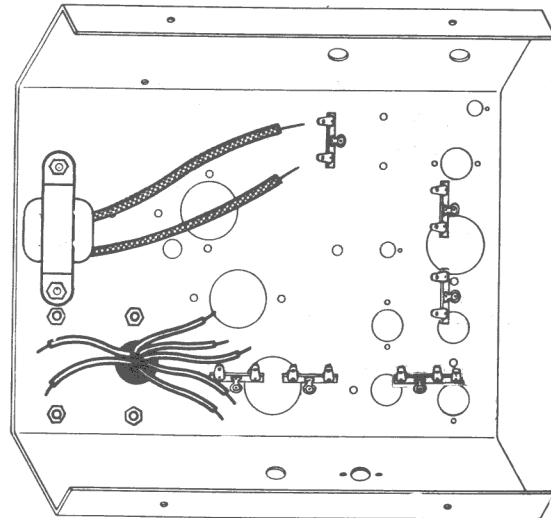
Fig. 14-2

Procedure.

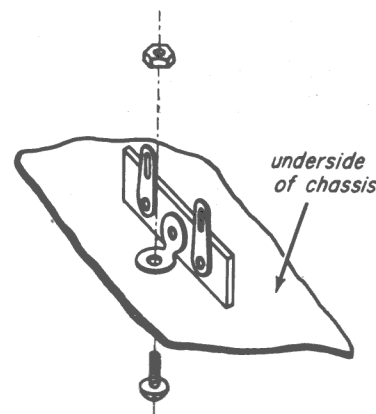
Step 1. Place the chassis upside down and place it on two wooden blocks, as shown in Fig. 14-2a. These blocks, which you can make from 2" x 4" lumber, will keep the chassis in position for easy working.

Step 2. Locate the two holes that were punched on the chassis for the mounting of the choke, shown in Fig. 14-2b.

Step 3. Place the two mounting holes on the choke over the holes in the chassis, and fasten the choke to the chassis with #6 lockwashers, 6-32 x 1/4 inch screws, and nuts. This is the permanent position for this choke.



(a)



(b)

Fig. 14-3

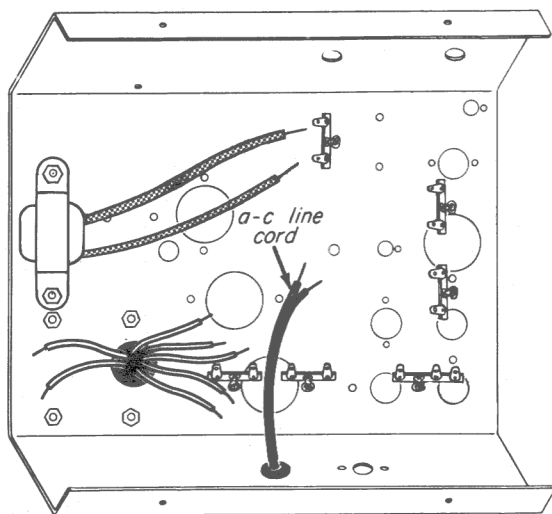
JOB 14-3

To mount six terminal strips on the underside of the chassis.

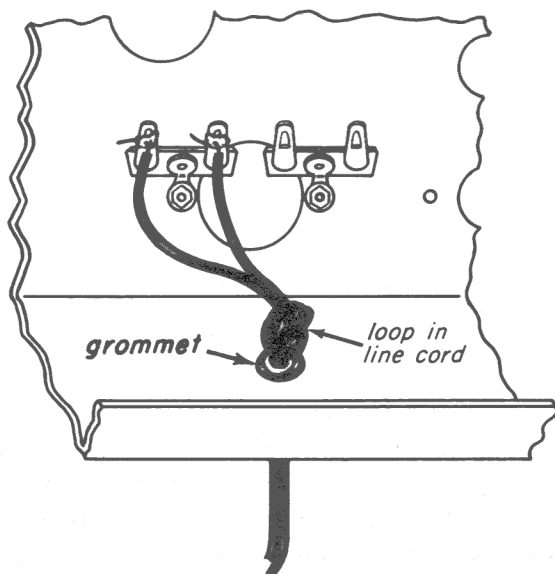
Procedure.

Step 1. By comparing Fig. 14-3a with your chassis, locate the six holes where the terminal strips are to be mounted. Note that five of the strips have two terminals and that one has three terminals. Select these six terminal strips from the hardware, together with six 6-32 nuts and six 6-32 x 1/4 inch screws.

Step 2. Mount each of the terminals, one at a time, and fasten them to the chassis with 6-32 x 1/4 inch screws and nuts as in Fig. 14-3b. These are being mounted tempor-



(a)



(b)

Fig. 14-4

arily, so that it is not necessary to use lockwashers. However, be sure to fasten each tightly in position so that the terminal will not slip around as you work on them.

JOB 14-4

To wire the line cord, choke, and transformer windings to the terminal strips.

Procedure.

Step 1. Place a 1/4-inch rubber grommet in the hole punched out for the line cord that

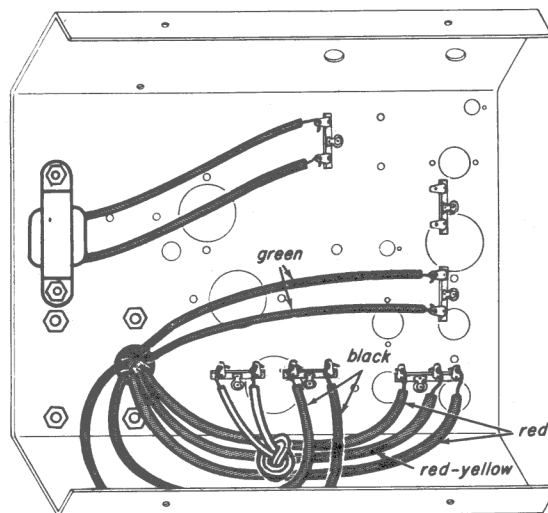


Fig. 14-5

is in the rear of the chassis. Thread about 6 inches of the line cord through this hole, as shown in Fig. 14-4a. Make a single loop in this length, as shown, and solder the tinned ends to the terminal strip, in Fig. 14-4b.

Note: The loop that you tie in the line cord prevents any strain on the soldered connections to the terminal strip, should you accidentally pull on the cord after the connections have been made. This is a standard practice in the manufacturing of radio and television receivers.

Step 2. Solder the two red and one red-yellow transformer leads to the 3-lug terminal strip, as shown in Fig. 14-5. Make sure that the red-yellow lead is in the center.

Step 3. Solder the black transformer leads to the terminal strip and dress the wire as shown in Fig. 14-5.

Step 4. Solder the green transformer leads to the terminal strip as shown in Fig. 14-5.

Step 5. Solder the choke leads to the terminal strip shown in Fig. 14-5.

JOB 14-5.

To connect four 1.5-volt dry cells in series aiding.

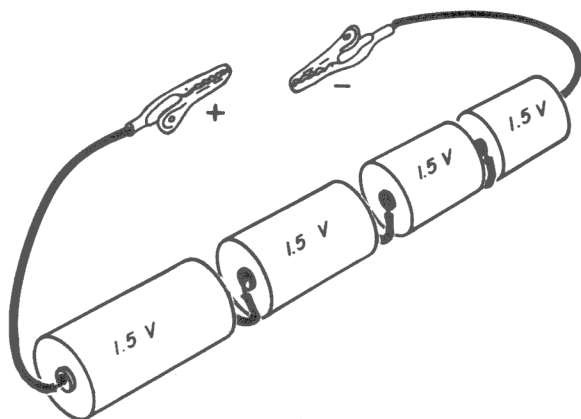


Fig. 14-6

Procedure.

Step 1. Lightly clean the terminals of the four 1.5-volt cells from Kit 7

Step 2. Using 2-inch lengths of hookup wire, connect the negative terminal of one cell to the positive terminal of the next cell until all four cells are connected in series aiding to form a 6-volt battery. Solder these connections.

Step 3. Solder 6-inch leads to the positive and negative terminals of this 6-volt battery, and to the free end of each lead solder an alligator clip, as shown in Fig. 14-6.

You are now ready for the first experiment.

EXPERIMENT 14-1

To study the effect of closing and opening a d-c circuit containing inductance.

Procedure.

Step 1. Clip one lead of the battery to one lead of the filter choke, as in Fig. 14-7. Just for a moment, touch the other battery clip to the other end of the filter choke. Do this carefully several times and watch for a spark. Does the spark occur when you make the circuit or break the circuit? Do you know why this should be so? Disconnect the battery from the filter choke.

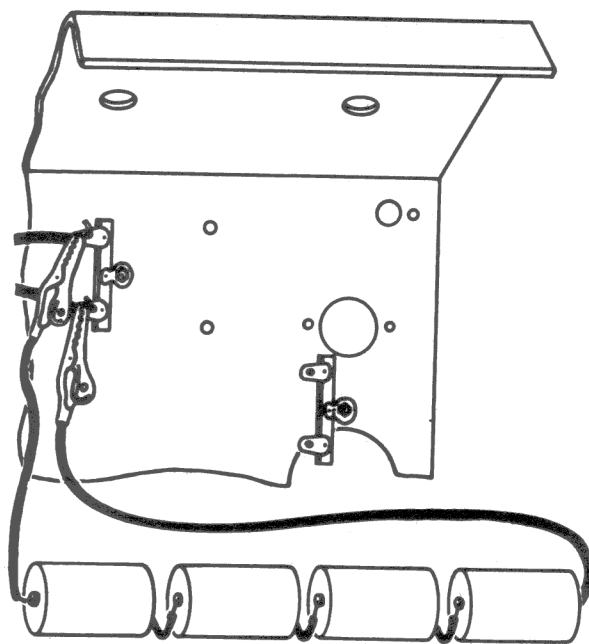


Fig. 14-7

Step 2. Insert the neon lamp in the pilot-lamp socket and connect it across the battery terminals. Does the neon lamp light?

Step 3. Solder the pilot lamp socket leads across the filter choke, as shown in Fig. 14-8.

Step 4. Clip one lead of the battery to one lead of the choke. Touch the other battery clip to the other lead of the choke, making and breaking the circuit. Does the neon lamp light? When does it light – when the circuit is closed or when it is opened?

Step 5. Unsolder the pilot-light socket from the choke.

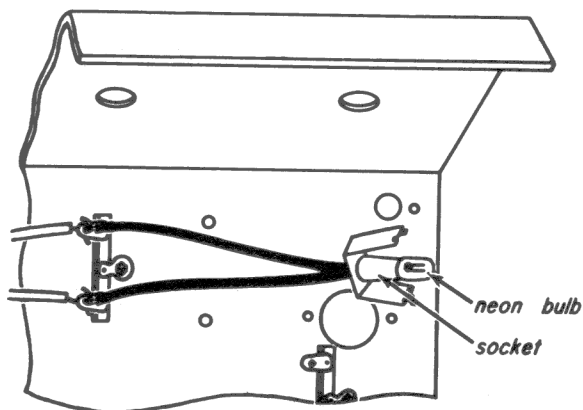


Fig. 14-8

Discussion. If you followed the directions carefully, you found in Step 1 that a spark occurs whenever the battery is disconnected from the filter choke. This happens because, whenever the battery is connected across a coil, current flows through the coil and a magnetic field is built up around the coil. Energy is stored in this magnetic field. When the circuit is opened, the current stops flowing and the magnetic field collapses. The collapsing magnetic field cuts the turns of the coil and induces a voltage in it. The amount of voltage depends upon the speed of collapse of the field and the number of turns in the coil. If the rate of collapse is fast enough and the inductance of the coil is great enough, the induced voltage will be enough to cause an electric current to jump the air gap and produce a spark.

In Step 2, the neon lamp did not light because the *firing* voltage of a neon lamp of this type is about 90 volts on d.c. and the battery voltage is only six volts. However, in Step 4, the neon lamp did light whenever the circuit was broken. This shows that the collapsing field produces at least ninety volts at the terminals of the choke. Since this voltage lasts only for an instant, your meter would not measure it because the needle can't move that fast. The neon lamp however, lights instantly once the firing voltage is reached, so we may use it here to show the presence of the induced voltage.

EXPERIMENT 14-2

To study the polarity of the induced voltage produced in d-c circuits.

Procedure.

Step 1 Remove the test leads from the multimeter. Insert the phone tips of the shielded test lead you made in Experiment Lesson 2 in the COMMON and POSITIVE meter jacks. Turn the FUNCTION switch to the DC position.

Step 2. Clip the other end of the shielded test lead to the two red-lead lugs of the high-

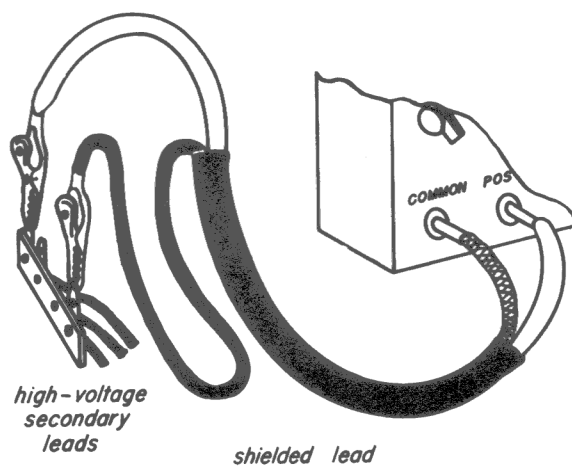


Fig. 14-9

voltage-secondary terminal strip. If connected properly, it should look like the set-up in Fig. 14-9.

Step 3. Clip the negative lead of the battery to one end of the power transformer primary winding.

Step 4. Touch the positive battery clip to the other lead of the primary winding, and observe the meter both when the circuit is closed and when it is opened. Is a voltage induced in the primary winding when the circuit is closed? Is a voltage induced in the circuit when the circuit is opened? Is there any difference between these two voltages? Why?

Step 5. Reverse the battery connections, and repeat Step 3. How do the results compare with those in Step 3? Why?

Step 6. Disconnect your circuit.

Discussion. You found in Step 4 that a voltage is induced in the secondary winding in one direction when the circuit is closed and in the other direction when the circuit is opened. This is because, when the circuit is closed, the current flow in the primary causes a magnetic field to build up. As the magnetic field is increasing, it cuts the turns of the secondary winding and induces a voltage in it. When the circuit is open, the field collapses, and cuts the turns of the secondary winding in the *other* direction, thus inducing a voltage in the opposite direction.

In Step 5, since the battery is reversed, the polarity of the induced voltages is reversed.

EXPERIMENT 14-3

To study the action of an inductance on d.c. and on a.c.

Preparation. Beginning with the next experiment, you will use the a-c line voltage across various circuits composed of resistors, inductors, and capacitors. Read the instructions for each experiment thoroughly and study the wiring diagram of the circuit carefully. Connect your circuit exactly as in the instructions. The following safety rules for working with a-c circuits are important enough for you to memorize. Follow them so thoroughly that they become an automatic habit

1. Always double check your wiring before connecting a-c power to your circuit.

2. Connect the a-c plug of the line cord to the a-c outlet only after all other connections have been made. *Never* connect the line cord to the a-c outlet and then make your circuit connections.

3. Always disconnect the a-c power by *removing the plug from the outlet* when making any changes in the circuit wiring.

4. Be careful not to come into contact with any exposed wiring.

5. Always hold your meter leads by the insulated test prods and keep your hands and fingers clear of the metal tips.

Procedure.

Step 1. Solder the 390-ohm resistor to the lugs of the unused terminal strip on the chassis. Then connect the resistor and the filter choke in series, as shown in Fig. 14-10.

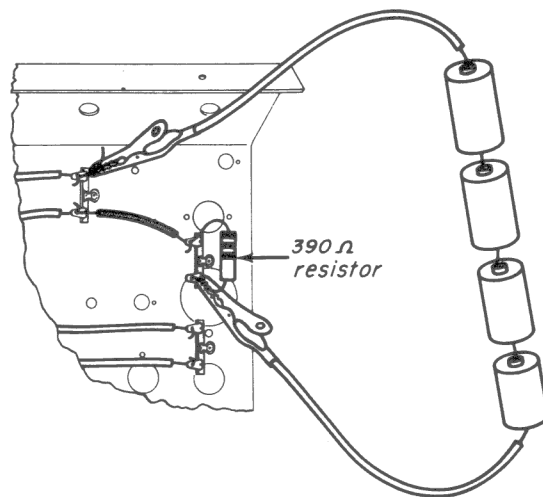


Fig. 14-10

Step 2. Clip the 6-volt battery across the terminals of the circuit, as shown in the figure.

Step 3. Measure the d-c voltage across the resistor and record it here:

2.9v

Step 4. Measure the d-c voltage across the inductor and record it here:

2.9v

Step 5. Remove the battery clips from the circuit.

Step 6. Connect the 6-volt winding of the power transformer across the 390-ohm resistor and inductor in series as shown in Fig. 14-11a.

Step 7. Connect the transformer primary across the a-c power-cord terminal strip, as in Fig. 14-11b.

Step 8. After checking your circuit, connect the a-c plug to an a-c outlet.

Step 9. Measure the a-c voltage across the ends of the secondary winding (green lead)

and record it here:

6V

Step 10. Measure the a-c voltage across the resistor and record it here:

6V .2

Step 11. Measure the a-c voltage across the inductor and record it here:

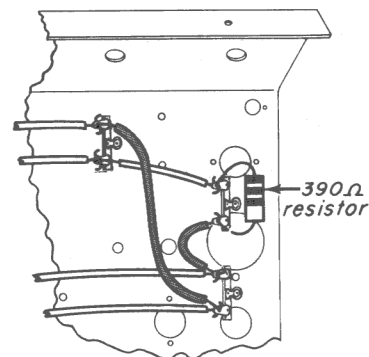
6V

How does the voltage across the inductor on a-c compare with the voltage across the inductor on d-c?

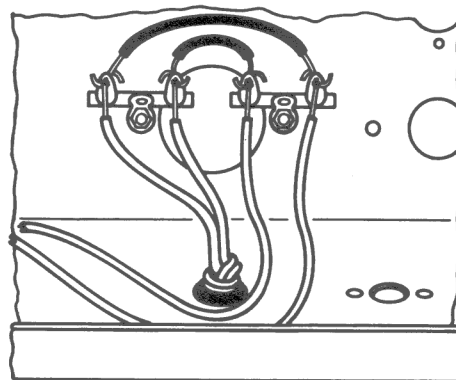
Step 12. Remove the line cord from the a-c outlet.

Discussion. This experiment demonstrates the property of inductance and inductive reactance. With a d-c battery connected across the inductor and resistor in series, the voltage divides across them in proportion to the d-c resistance of each. Since the 390-ohm resistor and the 400-ohm choke have almost equal d-c resistances, the 6-volts from the battery is almost equally divided between them.

With alternating current applied to this same circuit, the voltage division changes greatly. Here the inductive reactance of the coil comes into play, and it is so much larger than the 390 ohms of the resistor that almost all of the a-c voltage appears across the inductor.



(a)



(b)

Fig. 14-11

In the next experiment, we shall see how the inductance and the inductive reactance of an inductor may be measured.

EXPERIMENT 14-4

To study one method of measuring the inductive reactance and the inductance of an inductor in a sine-wave a-c circuit.

Procedure.

Step 1. Carefully unsolder the 390-ohm resistor from the terminal strip. Save the resistor for future experiments.

Step 2. Temporarily solder a 10,000-ohm resistor at the terminal strip to which the 390-ohm resistor had been originally soldered.

Step 3. Plug the line cord into the a-c outlet.

Step 4. Measure the voltage across the

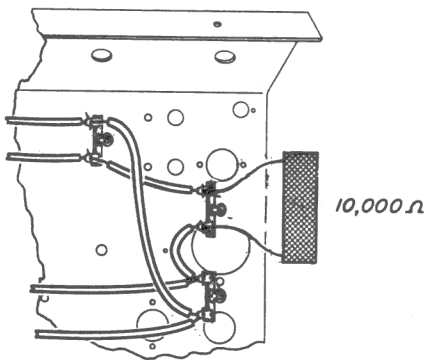


Fig. 14-12

resistor and record it here:

Low Voltage
Second.
6.6 V

4.6 V

Step 5. Measure the voltage across the choke and record it here:

3 V

Step 6. Remove the line cord from the a-c outlet.

Note: The resistor, the choke, and the a-c power line form a series circuit, so the current flowing in the choke is the same as the current flowing through the resistor. Therefore, if you find I_R you will find I_L at the same time.

Step 7. Calculate the current in the circuit using the known value of resistance (10,000 ohms) and the voltage across it:

$$I = \frac{E_R}{R} = \frac{4.6}{10,000} = .00046$$

Step 8. Calculate the inductive reactance of the coil:

$$X_L = \frac{E_L}{I} = \frac{3}{.00046} = 6521 \Omega$$

Step 9. Calculate the inductance of the coil:

$$L = \frac{X_L}{2 \pi f} = \frac{6521}{2 \cdot 3.14 \cdot 60} = \frac{6521}{37680} = .173 \text{ mH}$$

Discussion. The filter choke that you have just been measuring has a d-c resistance of 400 ohms. When placed in a sine-wave a-c circuit, the choke offers resistance as well as inductive reactance to the a.c. (This is true of all practical inductors, as you will learn in a later lesson.) So, in Step 8, you actually found the impedance of the choke. However, since the inductive reactance in this coil is very high compared to the coil resistance (400 ohms), the impedance can be considered equal to the inductive reactance.

If the line voltage in your home is about 120 volts, the voltages you measured in this experiment are approximately as shown below:

Voltage across the 6-volt secondary 7.3 volts

Voltage across the resistor 5.7 volts

Voltage across the filter choke 3.6 volts

Current in the series circuit
(calculated) 0.00057 amperes

Inductive reactance of the choke
coil (calculated) 6,315 ohms

Inductance of the choke coil
(calculated) 16.7 henrys
(approx)

Your figures may not agree exactly with these because of line voltage differences and the slight differences in manufacture between the circuit parts you used and those used in our laboratory. Therefore, the readings are given to you only as a guide. However, your figures should come within 20

$$\begin{array}{r} 37680 \overline{) 6521.000} \\ \underline{37680} \\ 275300 \\ \underline{263760} \\ 115400 \end{array}$$

$$\begin{array}{r} 6521 \overline{) 42286} \\ \underline{42280} \\ 60 \\ \underline{60} \\ 0 \end{array}$$

percent of ours. Naturally, the more careful you are in reading your meter, the more accurate your figures will be.

The inductance of this choke is rated by the manufacturer as 8 henrys at 50-ma direct current. The reason that the inductance is specified in connection with a certain amount of direct current is twofold. First, this choke is designed to be used in power supplies, where, as you will see later, a certain amount of direct current flows through the choke. Second, the inductance of any inductor that has an iron or other high permeability core *changes with the amount of direct current flowing through the inductor*. This is due to the magnetic saturation effect described in an earlier lesson. An inductor can have effective inductance only when a changing current in the coil is able to produce a changing magnetic field. However, when direct current flowing through the inductor begins to saturate its core, a changing current in it cannot produce the same changing magnetic field. The effective inductance is therefore reduced. Thus the inductance of iron-core inductors must always be specified for a certain amount of direct current, such as 8 henrys at 50 ma. In this experiment, there is no direct current flowing through the inductor. Under these conditions, we therefore obtain a higher value of inductance than the manufacturer's rated value.

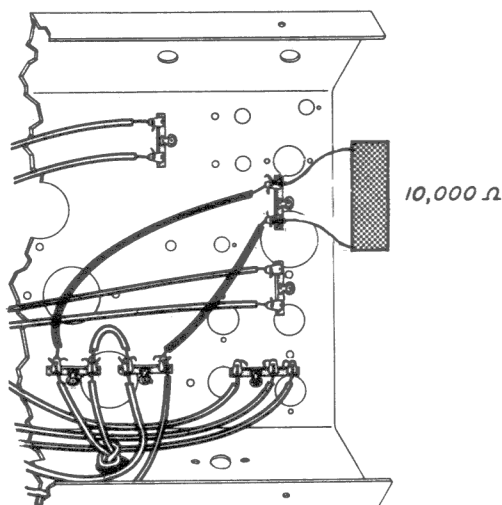


Fig. 14-13

EXPERIMENT 14-5

To measure the inductance of the primary of the power transformer and compare it with the inductance of the filter choke used in Experiment 14-4.

Procedure.

Step 1. Remove the lead that connects the choke with the 10,000-ohm resistor.

Step 2. Remove one lead that connects the transformer primary to the line-cord terminal strip.

Step 3. Connect the 10,000-ohm resistor in series with the transformer primary and the line cord, as shown in Fig. 14-13.

Step 4. After checking your circuit, insert the plug into an a-c socket.

Step 5. Measure the voltage across the resistor and record it here:

$$92\text{V} = E_R$$

Step 6. Measure the voltage across the primary winding and record it here:

$$32\text{V} = E_L$$

Step 7. Disconnect the line cord from the a-c outlet.

Step 8. Calculate the current in the circuit:

$$I = \frac{E_R}{R} = \frac{92}{10000} = .0092 \text{ amp}$$

Step 9. Calculate the inductive reactance of the primary:

$$X_L = \frac{E_L}{I} = \frac{32}{.000092} = 347,826 \Omega$$

Step 10. Calculate the inductance of the primary:

$$L = \frac{X_L}{2 \pi f} = \frac{347826}{376.8} = .920 \text{ h}$$

Discussion. Assuming a line voltage of about 120 volts, the results of your experiment should be as follows:

Voltage across the resistor 97 volts

Voltage across the primary winding 30 volts

Current in the series circuit
(calculated) 0.0097 amperes

Inductive reactance of the primary
(calculated) 3,093 ohms

Inductance of the primary
(calculated) 8.2 henrys

What would you say about the number of turns in the primary winding of the power transformer as compared to the number of turns in the filter choke? You know that the inductance depends partly upon the number of turns. Since the inductance is much less, the primary winding must have fewer turns.

EXPERIMENT 14-6

To study the effect of a shorted secondary winding of a transformer on the inductance and inductive reactance of the primary winding of the transformer.

Procedure.

Step 1. Use the circuit you connected in Experiment 14-5 (Fig. 14-13).

Step 2. Connect the leads of the 6-volt secondary winding together — that is, short them to each other.

Step 3. After checking your circuit, insert the line-cord plug into an a-c outlet. Then measure the voltage across the resistor and the voltage across the primary winding and record them here:

$$E_R = 120 \text{ v} \quad 0.4 \text{ v} = E_L$$

Step 4. Disconnect the line cord from the a-c outlet.

Step 5. Disconnect (unshort) the leads of the 6-volt secondary winding.

Step 6. Calculate the current in the circuit

$$I = \frac{E_R}{R} = \frac{120}{10,000} = .0120$$

Step 7. Calculate the inductive reactance of the primary winding:

$$X_L = \frac{E_L}{I} = \frac{.4}{.012} = 33 \Omega$$

Step 8. Calculate the inductance of the primary winding:

$$L = \frac{X_L}{2 \pi f} = \frac{33}{376.8} = .08 \text{ h}$$

Discussion. In this experiment, we see the effect of a shorted secondary winding on the primary winding. If your line voltage is about 120 volts, the results of your experiment will be as follows:

Voltage across the resistor 120 volts

Voltage across the primary winding 0.4 volts

Current in the series circuit
(calculated) 0.012 amperes

Inductive reactance of the primary
winding (calculated) 33.3 ohms

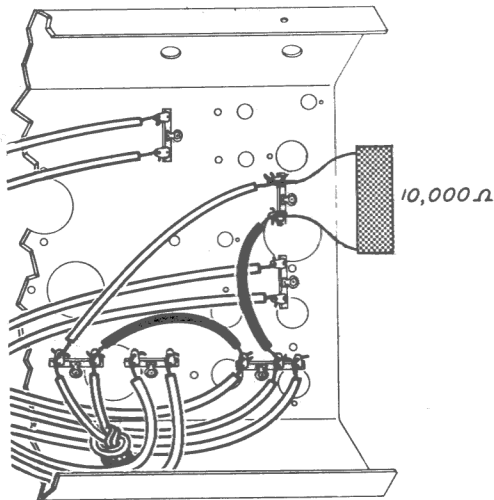


Fig. 14-14

Inductance of the primary winding
(calculated) 0.088 henrys

Notice that the inductive reactance and the inductance of the primary winding dropped considerably when the secondary winding was shorted. If the 10,000-ohm resistor were not in series with the circuit to limit the current, the current would also have increased considerably. This is because of the mutual inductance of any two windings of a transformer. The secondary winding has a voltage induced in it due to the changing flux produced by the primary. When the secondary winding is shorted, high current flows in the secondary. The flux produced by this current in the secondary is opposite in direction to the primary flux. In the case of a complete short circuit, the secondary flux almost cancels the primary flux, thus reducing the inductance of the primary to a very low value.

EXPERIMENT 14-7

To study mutual inductance further.

Procedure.

Step 1. At the primary, unsolder the lead that connects it with the 10,000-ohm resistor and solder the lead of the 10,000-ohm resistor, instead, to the red-yellow terminal of the high-voltage winding.

Step 2. Remove the wire that connects the transformer primary with the line-cord terminal.

Step 3. Connect the free end of the line cord to one of the red leads of the high-voltage secondary winding.

Step 4. Check your circuit with Fig. 14-14. If it is correct, plug the line cord into the a-c outlet.

Step 5. Measure the voltage across the resistor and record it here:

$$E_R = 51 \text{ V}$$

Step 6. Measure the voltage across half of the high-voltage secondary winding and record it here:

$$E_L = 76 \text{ V}$$

Step 7. Disconnect the line cord from the a-c outlet.

Step 8. Calculate the current in the circuit:

$$I = \frac{E_R}{R} = \frac{51}{10,000} = .0051 \text{ amp}$$

Step 9. Calculate the inductive reactance of one half of the high-voltage secondary:

$$X_L = \frac{E_L}{I} = \frac{76}{.0051} = 15,000 \Omega$$

Step 10. Calculate the inductance of one half of the secondary:

$$L = \frac{X_L}{2 \pi f} = \frac{15,000}{376.8} = 39 \text{ h}$$

Step 11. Unsolder the lead that connects

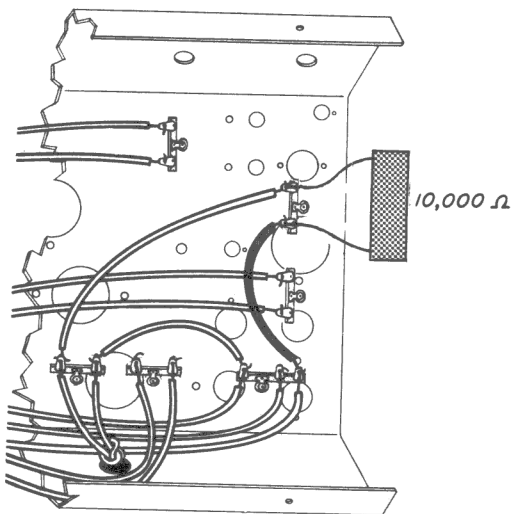


Fig. 14-15

the 10,000-ohm resistor to the high-voltage secondary from the red-yellow lead and connect it, instead, to the free red lead of the high-voltage secondary, as in Fig. 14-15.

Step 12. Measure the voltage across the resistance and record it here:

$$E_R = 18V$$

Step 13. Measure the voltage across the secondary winding and record it here:

$$E_L = 108V$$

Step 14. Calculate the current in the circuit:

$$I = \frac{E_R}{R} = \frac{18}{10,000} = .0018$$

Step 15. Calculate the inductive reactance of the secondary:

$$X_L = \frac{E_L}{I} = \frac{108}{.0018} = 60,000 \Omega$$

Step 16. Calculate the inductance of the

entire secondary winding:

$$L = \frac{X_L}{2 \pi f} = \frac{60,000 \Omega}{376.8} = 159 H$$

Step 17. Disconnect the line cord from the a-c outlet.

Discussion. Based on a line voltage of 120 volts, the results you should obtain from this experiment are as follows:

For one half the secondary winding:

Voltage across the resistor 54 volts

Voltage across half the secondary 76 volts

Current through the circuit
(calculated) 0.0054 amperes

Inductive reactance of one-half
the high-voltage secondary
(calculated) 14,074 ohms

Inductance of one half the
secondary high-voltage
(calculated) 37 henrys

For the entire secondary

Voltage across the resistor 19 volts

Voltage across the entire secondary 106 volts

Current through the circuit
(calculated) 0.0019 amperes

Inductive reactance of entire
secondary (calculated) 55,789 ohms

Inductance of entire secondary
(calculated) 148 henrys

This experiment shows the effect of mutual inductance between inductances that are in series aiding. In this case, the two halves of the secondary winding are tightly coupled (linked) together because they are wound close to each other on the same core. Note that the inductance of each half of the

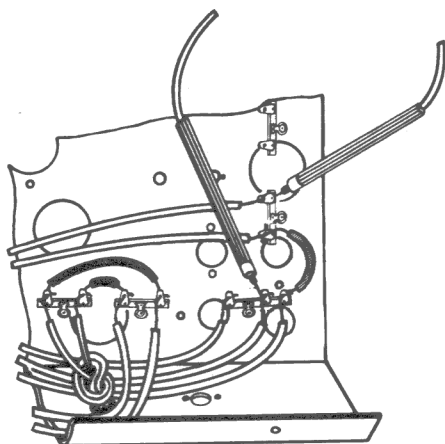


Fig. 14-16

secondary is 37 henrys, but the inductance of both halves in series is not twice as much but almost four times as much. The increase is due to the mutual inductance between the two halves of the secondary.

EXPERIMENT 14-8

To study mutual inductance still further.

Procedure.

Step 1. Remove the two leads that connect the 10,000-ohm resistor to the circuit.

Step 2. At the resistor terminal strip, unsolder the lead that connects it with high-voltage secondary and solder it, instead, to one lug of the 6-volt terminal strip, as shown in Fig. 14-16.

Step 3. At the resistor terminal strip, unsolder the lead that connects it with the line-cord terminal strip; solder it, instead, to one lug of the transformer primary terminal strip.

Step 4. At the high-voltage terminal strip, unsolder the lead that connects it with the line-cord terminal strip and solder it, instead, to one lug of the transformer primary terminal strip. (When these changes have been made, check your connections with Fig. 14-16.

Step 5. If the connections are correct, plug the line cord into the a-c outlet.

Step 6. With your multimeter set up for operation on the 300 VAC range, measure the voltage between the free end of the 6-volt winding and the red-yellow lug of the high-voltage secondary, as shown in Fig. 14-16. Record the voltage here:

268v

Step 7. Disconnect the line cord from the a-c outlet.

Step 8. Reverse the connection to the 6-volt winding. To do this, unsolder the lead that connects it with the high-voltage secondary and solder it instead to the other lug of the 6-volt winding. Check your work with Fig. 14-17.

Step 9. If you have made this change correctly, plug the line cord into the a-c outlet.

Step 10. Measure the voltage between the free end of the 6-volt winding and the red-yellow lug of the high voltage secondary winding and record it here:

252v

Step 11. Disconnect the line cord from the a-c outlet.

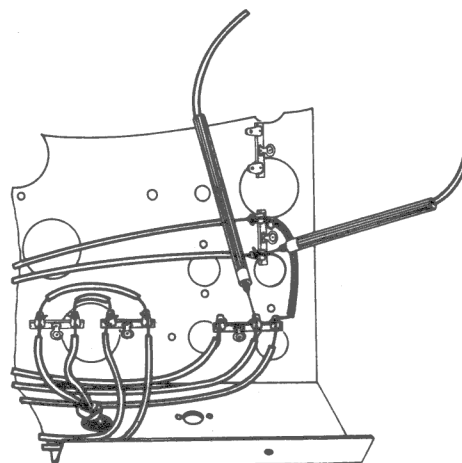


Fig. 14-17

Step 12. Remove all of the leads that connect one transformer winding with another. Leave each winding soldered to its terminal strip.

Step 13. Can you explain the difference between the two voltage readings?

Discussion. In this experiment, you connected two transformer secondary windings together in series. Depending on the value of your line voltage, you found that there was a

difference of about 12 volts between the first reading and the reading taken when the connection was reversed. When the two secondary windings were connected in series aiding, the voltages added. When the windings were connected in series opposing, the smaller voltage subtracted from the larger. When two inductors are connected so that they aid each other, we say that they are in phase. When they are connected so that they oppose each other, we say that they are out of phase or that they *buck* each other. The proper phasing of inductors is very important in many radio and television circuits.

$$L \text{ (in henries)} = \frac{\text{induced emf (volts)}}{\text{current (amps)}}$$

$$L = \frac{6}{5} = 1.2 \text{ h}$$